1 Objects of Desire

Apple's iPhone is an icon of the modern consumer electronics industry. It created a frenzy when it was released in the USA in July 2007, and in other parts of the world later in the same year. The iPhone is a mobile phone, but it can also connect to wireless computer networks; it is a music and video player, an atlas, a digital camera, a photograph album, a web browser, a calendar and an address book. There is only one button – all the other controls are accessible via a very responsive and, most people would agree, easy-to-use touch screen. That screen has 'multitouch' technology, with which the user can pinch or squeeze photos and web pages using two fingers, to zoom in and out. The iPhone was a success even before its release, and it quickly became an object of desire. To many people, it seemed like a real leap forward in technology – as if nothing else like it had ever existed. While there was genuine innovation in the design of this product – along with clever marketing and exquisite styling – there was no great technological leap forward involved in its development. It is a multi-featured 'smartphone' – and many other such devices already existed, albeit without quite the visual impact nor, many people would say, the same ease of use.

The point is that although the face of consumer electronics changes quite rapidly, the underlying technologies develop much more gradually. Processor speeds increase, but the processors themselves are still based on integrated circuits

Apple's iPhone – a digital object of desire.

COURTESY OF APPLE

made from semiconductors. Data storage and displays become cheaper and better, but they are still hard disks, solid-state memory and LCDs or plasma screens. And services such as wireless and mobile Internet access roll out more extensively and with enhanced speeds, but they are still based on digital information encoded in radio signals. All of this rapid development leads to generations of

devices that are better equipped and more widely available than previous ones. Specific features and styling are hard to predict in new products, but for years to come, all new consumer electronics products will be built around the same core set of technologies.

Although the face of consumer electronics **changes** quite rapidly, the **underlying technologies develop** much more gradually

The iPhone will not be such big news two years down the line, and may well have been replaced in many consumers' minds, if not their pockets, by products that are equally innovative. But those new products will still work in basically the same way. And so, in constructing a vision of tomorrow's world of consumer electronics, we set out by deconstructing today's.

There is a huge range of items that could be tagged as 'consumer electronics'. They include simple children's toys, quartz clocks, watches and stopwatches, battery chargers, novelty doorbells, electronic calculators, radio-controlled model cars and even musical birthday candles. Also, appliances such as fridges, food mixers and washing machines increasingly rely, in part at least, upon electronics. Usually, however, the definition of consumer electronics is much narrower: it is normally restricted to digital devices that help us communicate, that keep us entertained and that give us access to information. That still encompasses a huge range of products, including desktop and portable computers, mobile phones, thin, flat-screen televisions, e-book readers, portable navigation units, small robots, personal media players, digital radios, digital picture frames, computer

printers and scanners, digital cameras and camcorders, set-top television boxes, satellite receivers, personal video recorders, projectors and games consoles. All things I desire.

The kind of desirable items listed above is sometimes described as 'brown goods' – because in the early days of the consumer electronics industry, radios, telephones and televisions were commonly boxed in brown Bakelite, an early plastic. Modern, hi-tech brown goods are available in the high street, in shopping centres and, of course online. They are normally grey or white or cased in sleek brushed metal – rarely brown. Whatever colour they are, they are extremely popular: in 2007, consumers worldwide spent more than £165 billion ($340 billion) on these gadgets (note: in this book, as in most books, magazines, websites and news reports nowadays, one billion equals one thousand million – even in Britain – and one billionth equals one thousand-millionth). In that year, sales of mp3 players and digital cameras rose by 20% – as they had been doing for the past five years – and sales of LCD and plasma screens were around 50% more than in 2006. Sales of mobile phones reached 1.2 billion – again, an increase of around 20% on the previous year.

Whatever you call them, **however** you classify them – and **whatever their reason for being** – by buying into these 'must have' **gadgets**, we are **dramatically changing** the way we socialise, do **business** and organise our lives

Playing the Game

One of the devices that best illustrates the rapid advance of consumer electronics, and its increasing influence on the lives of millions of people worldwide, is the games console. The two most sophisticated games consoles have enormous computing power, thanks to their 'multi-core' processors. At the heart of Microsoft's Xbox 360 is a triple-core processor – basically, three processors working simultaneously. Sony's PlayStation 3 has a 'Cell' processor, which has a single processing core, but with six separate processing elements built-in, all working in parallel with the main core.

The feature of video games that has changed most noticeably in the past decade is the quality of the on-screen graphics. The most powerful consoles can now produce realistic output at the quality and resolution of high-definition television. Inside a games console, a powerful graphics processor prepares the signal for output to a display. The graphics processor carries out a significant amount of the processing power required for games – often including working out how objects will look from different viewpoints as the player moves around in the game. Just as important as what the game looks like is how it feels to play. In Assassin's Creed, released in November 2007, the game designers endowed incidental (non-player) characters with individuality and realistic behaviour. Players can explore three huge virtual cities, each rendered in exquisite detail. Inside the game environment, the player can jump from building to building, gripping anything that protrudes from any building.

In some countries, gaming is so much part of people's lives that it has become a popular spectator sport. In South Korea, two television

channels are dedicated to video games, and star players release DVDs of their best games. In the countries where gaming is most popular – South Korea and Japan – professional gamers have huge followings. In 2005, a hundred thousand people turned out to watch the progress of South Korean pro-gamer Lim Yo Hwan as he played his favourite game.

The two most powerful games consoles on the market are Microsoft's Xbox 360 and Sony's PlayStation 3. Both are so-called 'seventh generation' machines – which gives you an idea of how long the leapfrog game of technological progress has been going on in the computer gaming industry.

Whatever you call them, however you classify them – and whatever their reason for being – by buying into these 'must have' gadgets, we are dramatically changing the way we socialise, do business and organise our lives. So what are they, really? And what do they have in common? If we are to understand how these gadgets might evolve, we need to know something about how today's versions work. So if you are the kind of person who is familiar with terms such as RAM and gigahertz, but you don't really know how it all works, then the following should get you up to speed. It will get a little bit involved, but I think it's important that people have an idea of the magic that goes on inside their treasured gadgets. After all, love them or hate them, desire them or not, these devices work hard for you every second they are switched on.

Computers Everywhere

You might think of your gadgets in two categories: computers and the rest. But what makes a computer a computer and other devices just, well, other devices? You may be surprised to find out that there is little difference – that all modern consumer electronics devices are, in fact, computers. That simple mp3 player? A computer. That digital camera? Likewise. Even a digital television is a computer.

A computer is defined by its 'architecture' – the existence and organisation of the main components inside. In particular, every computer has a central processing unit (a processor) to carry out sets of instructions and perform calculations, working memory to store those instructions and the interim results of calculations, longer-term storage, and some kind of input and output.

This is why, almost without exception, all modern consumer electronics products are computers. Every set-top box, every wireless router, every printer, scanner

and even every CD and DVD player is a computer. Many of these devices are dedicated to carrying out a limited set of functions. All of those functions are realised by a single program called the firmware. This program loads when you switch on the device.

To reinforce this idea that every digital device is a computer, consider the fact that you can reprogram many of what you might think of as dedicated devices to do other things. For example, hobbyist hackers can install their own firmware and software in their games consoles, media players and even digital cameras. In 2007, an astrophysicist at the University of Massachusetts, USA, loaded a different operating system onto six Sony PlayStation 3 video game consoles, then linked them together to make a single, extremely powerful supercomputer.

Electric currents rush around inside chips like these, hidden from view inside your digital gadgets, making magic happen.
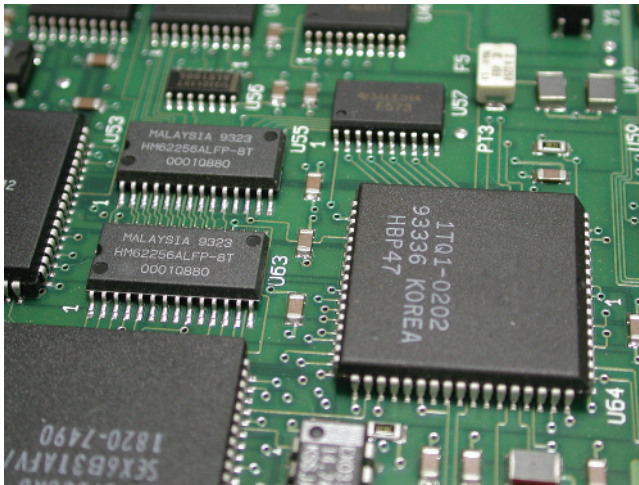
Dedicated Devices

Electronic products that have limited, specific functions – rather than the ability to load and run a variety of programs as personal computers do – are called dedicated or embedded devices. They are often furnished with a specially designed and custom-built chip called an application-specific integrated circuit (ASIC). There is an ASIC inside your digital camera, in your broadband modem and in your wireless router. An ASIC is a complex circuit specially designed and custom-built to enable just the functionality of each device. Having an all-in-one solution like this keeps power consumption low and cost down and improves performance and reliability. Most gadgets also contain another type of integrated circuit, with the immediately forgettable name of 'application-specific standard product' (ASSP). These circuits carry out specific functions, such as processing sound or video or producing a radio frequency signal for a wireless device but no more. So this is a 'modular' approach to electronic product design, since devices can be built with a number of 'off the shelf' ASSP chips, each with a different function.

Solder a few ASSPs and an ASIC onto a circuit board together with a memory chip and load a firmware program into the memory chip; connect the whole thing to a power supply and a large LCD screen – and a video source – and box the lot in a steel and plastic casing, and you have a high-definition television. Obviously, it is a lot more complicated than that, but that is the basic recipe. There are ASICs and ASSPs at the heart of mobile phones, in personal video recorders, network routers, and set-top boxes, and in most other dedicated devices.

The personal computer (PC) lies at the core of our digital existence – as it has been for increasing numbers of people since the early 1980s. It is a general purpose device. At its heart is a microprocessor – a more flexible and more powerful integrated circuit than you would find in a device dedicated to a limited set of functions. The microprocessor enables a computer to load and run any number of different programs. In 2007, more than one hundred million desktop, laptop, notebook and 'ultra-portable' personal computers were sold to consumers worldwide. Another 150 million went to business customers. Modern mobile phones can do a lot more than just make and receive phone calls and send and receive text messages. For that reason, they really are closer to what we would think of as computers. They too have a microprocessor.

The Numbers Represent

We've all heard about the Digital Revolution. Today's consumer electronics products – general-purpose PCs and smart phones as well as dedicated gadgets – are all digital devices. And 'digital' is the future. The New York journalist Walt Mossberg has said that 'We are in the path of a digital tidal wave.' So what does 'digital' really mean? It's simply that our gadgets represent information and programs as numbers. The microprocessor at the heart of a computer is a number cruncher: all it does is manipulate numbers, albeit extremely rapidly. As processors become faster – able to do more number-manipulations per second – they are able to process digital information more rapidly. And that digital 'information' is typically composed of images, video, sound, presentations and programs. So, as consumer electronics move ahead, we are more easily able to store and manipulate this kind of information – for convenience, information and entertainment. So just how is it possible to represent pictures, sound and video as numbers?

Consider digitising an image. The simplest way is to break down an image into a large number of dots or squares. Then, each of these picture elements, or pixels, can be assigned numbers based on the brightness and colour at that point in the image. The collection of all these numbers will successfully represent the image. A computer can use the numbers to reconstruct the image on a monitor or print it. The more pixels there are, and the more numbers are used per pixel, the better the detail in the digitised image. This is why good-quality digital images take up relatively large amounts of storage space on hard disks or memory cards. It is also why digital cameras have sensors that can measure brightness and colour at millions of points in an image.

It is easy to extrapolate from digitising individual images to digitising video, which is composed of a sequence of digitised still images, or frames. In practice, there are different schemes by which the numbers are arranged in the files that represent digital images and digital video. For example, there is 'meta-data' – information relating to the camera make and model, the program used to manipulate it, the date it was created and the image size. But the principle is straightforward.

The New York journalist Walt Mossberg has said that 'We are in the path of a digital tidal wave'

Audio – sound signals – can be represented numerically in a similar way. Sound is caused by variations in air pressure, which spread out in all directions as waves. If a microphone is near to a source of sound, it produces a varying electric voltage that matches the sound waves. In fact, the variations in voltage form a direct copy,

Digitising an image – break the image up into tiny picture elements, or pixels, and assign a number to each depending on its colour. The more pixels and the more numbers used, the better the representation of the image will be.

246, 81, 17   164, 25, 6
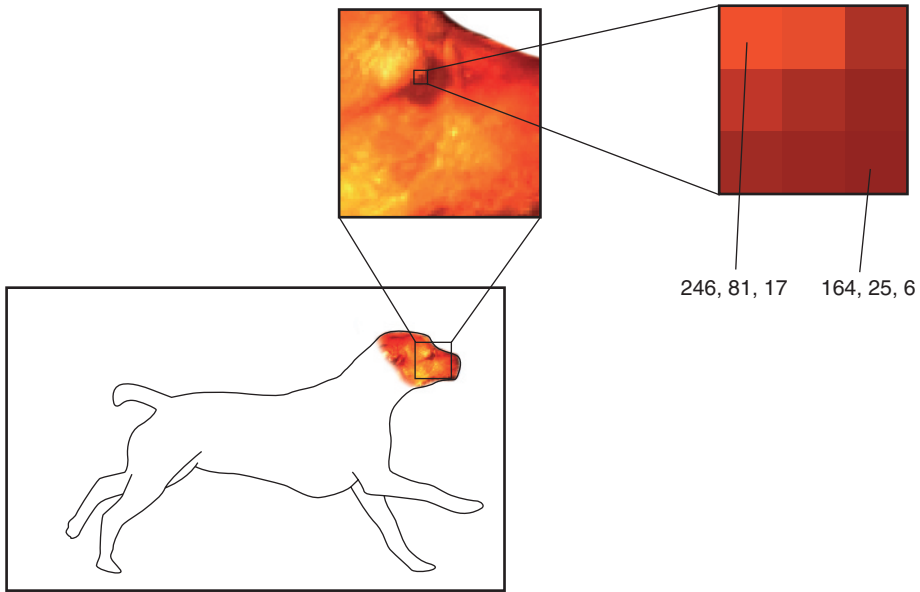
or analogue, of the sound wave. An electronic circuit called an analogue-to-digital converter measures, or 'samples', the voltage thousands of times each second. So, digital sound is simply a stream of numbers that represent the air pressure in the original sound. If you drew a graph using those numbers, it would look exactly like the original wave. Again, the more samples (per second in this case), the more faithful the digital representation of the original sound. And once again, there are different formats and clever ways of working with those streams of numbers, but the principle is clear and simple. Digital devices can manipulate and store those numbers. Using the right sets of instructions, a processor can even
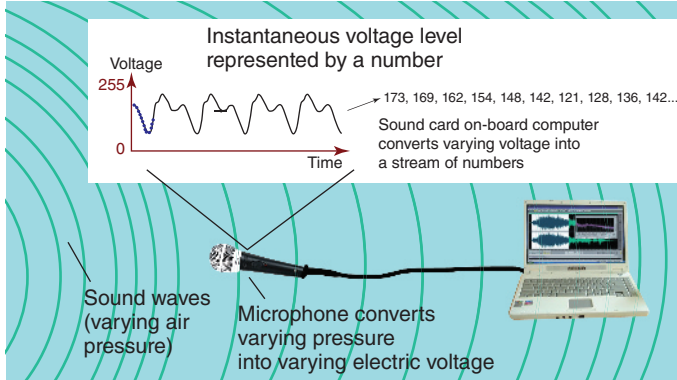
Just behind the lens of a mobile phone's camera lies an image sensor like this one. It is made up of millions of individual sensing elements, each of which produces an electrical voltage that corresponds to how much light falls on it.
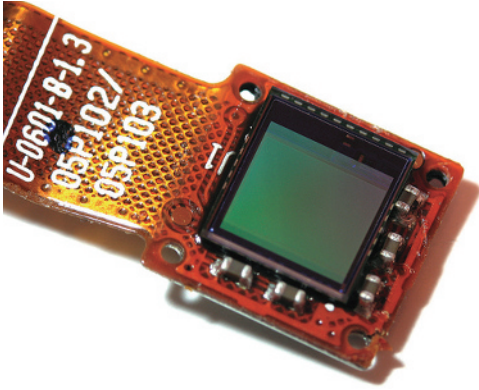
generate new sounds never heard, just by producing the relevant streams of numbers. This is the principle behind digital synthesisers, and most computer sound cards have synthesiser circuits on-board that are used to create sounds in some games or any programs where sound effects or electronically produced sounds are needed.

When you **download a web page**, or **pictures** and sounds from the **Internet**, you are receiving **millions** of individual numbers

Digitising sound – A microphone captures a sound wave as a varying audio signal. A digital device samples the level of the audio signal thousands of times every second. The more often the audio signal is 'sampled', the more faithful the representation and the clearer the sound will be.

Instantaneous voltage level represented by a number

Voltage

255

0

Time

173, 169, 162, 154, 148, 142, 121, 128, 136, 142...

Sound card on-board computer converts varying voltage into a stream of numbers

Sound waves (varying air pressure)

Microphone converts varying pressure into varying electric voltage

Alphabetic characters provide the simplest example of digitisation. There is a simple one-to-one coding scheme: each letter has a unique number to represent it. On most computers, upper case 'A' is represented by the number 65, for example. There are also codes for program instructions, as well as numeric characters, symbols and punctuation marks. Again, many different coding schemes exist, but every document or program stored on a computer really is simply a large collection of numbers. When you download a web page, or pictures and sounds from the Internet, you are receiving millions of individual numbers. This is why broadband Internet connections are opening up so many possibilities – when you can download millions of numbers every second, you can stream video and sound, while browsing web pages, for example.

All in Bits

If you could see the numbers that represent images, video, text or other characters written down as the computer 'sees' them, you would see endless arrays of ones and zeroes. Computers represent numbers using the binary system – also called 'base two' – while we humans tend to use the decimal system, or base ten. The binary system has only two available digits – 0 and 1; we use ten digits: 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. Inside a computer, the two binary digits, or 'bits', are commonly represented by voltages and electric currents, or by magnetic fields: 0 and 1 might be 'on' and 'off', 'high' and 'low', or 'magnetised this way' and 'magnetised that way'. In addition to the flexibility of being able to use any of these two-state systems to represent numbers, it is much easier to design circuits that can carry out arithmetic with just two digits than with ten. And, as we pointed out above, arithmetic is central to how computer processors work. It may seem amazing, but all your videos, images, text documents and software would be indistinguishable to the untrained eye if they were written out in their true binary form. They are all just large collections of ones and zeros.

Do you know the difference between a bit and a byte? Basically, it's a factor of eight. Why? The first personal computers used groups of eight bits to represent letters, numbers and other characters. Using eight bits, there are 256 different numbers available: from 00000000 (zero) to 11111111 (255). So, it was natural to measure amounts of information represented by binary numbers with a special unit – the byte, equal to eight bits. Nowadays, most personal computers – and other consumer electronics devices – are based on 32-bit groups; some on 64-bit groups. Still, the byte remains the dominant unit. One thousand bytes make a kilobyte (kB); one million bytes make a megabyte (MB); and one billion bytes make a gigabyte (GB). These terms are all familiar to anyone who uses the Internet, as are 'kilobits per second' – thousands of binary digits received or sent on a network each second. Megabits per second and

When you hold down the shift key on a computer keyboard and press the key marked 'A', the keyboard will send a stream of electrical pulses to the computer processor that represent the number 65 (in binary notation, 01000001).

gigabits per second are millions and billions of bits sent or received per second, respectively. All of these familiar units simply measure quantities of numbers. One kilobyte is simply one thousand eight-bit numbers – or even more simply, eight thousand 0s and 1s. Many consumers have only just got used to the term 'gigabyte' – since hard disk capacities used to be measured in megabytes. In the next few years, you will increasingly be hearing the term 'terabyte' – one terabyte is a thousand gigabytes.

To give you a bit more insight into what really goes on inside your digital devices, consider how many binary numbers are needed to represent one second of sound at 'CD quality'. Every second of CD-quality sound is represented by 44,100 individual

samples in each of the two stereo channels. Each sample is represented by a 16-bit binary number. So, when you record or play back CD-quality sound on a media player, a large number of binary digits must be processed every second to keep up. That number is 44,100 (samples) multiplied by 16 (bits per sample) multiplied by 2 (for stereo) – a total of 1,411,200 binary digits. This is equivalent to just over 1,411 kilobits, or slightly more than 176 kB (1,411 divided by 8, the number of bits per byte).

When sound is stored as an 'MP3' or other compressed format, near-CD-quality sound reproduction can be achieved with far fewer bits per second. This is done by altering the stream of numbers using clever mathematical functions called 'compression algorithms'. These algorithms are based on eliminating the bits corresponding to parts of the music that are too quiet or too high-pitched for our ears to hear well. A typical mp3 track downloaded from an online music outlet will be encoded at 192 kilobits per second – less than one-seventh the rate of the 'raw' CD-quality sound. As a result, a three-minute track stored on a digital music player will take up just over 4 MB of memory, while the same track at raw CD-quality will require nearly 32 MB. You notice this difference if you play an mp3 over a high-quality system or very loudly, but the difference is negligible most of the time, and those of us who buy music online would much rather have our music delivered swiftly and in acceptable quality than to wait for much longer for a better quality track. And it means we can have a capacity of many thousands of tracks on our media players, rather than a few hundred – if we so desire.

In the same way, we can work out how many bytes are needed to store a digital image. You can, of course, scan a photograph line by line, the scanner sending the relevant streams of numbers to a computer. But nowadays, most images are produced in digital form at source – inside a camera. Behind a camera's lens, images fall on a light-sensitive device – normally a charge-coupled device, CCD, which is a semiconductor chip similar to a processor or a memory chip. A typical CCD has millions of sensor elements on its surface, in a grid

pattern. A CCD like mine with a grid 3,264 wide by 2,448 high has a total of nearly 8 million sensors – and would be said to have a resolution of 8 megapixels. Each tiny sensor produces a voltage that depends upon the intensity of light falling on it. These voltages are digitised – represented by binary numbers – normally using 8 bits for each pixel. In most cameras, there is a coloured filter array on top of the CCD, which consists of red, green and blue filters in a regular arrangement. The result is that a camera produces three images – one red, one green and one blue – which produce a full-colour image when recombined. The processor inside the camera combines all the information to produce a 24-bit number for each sensor.

So, a 'raw' 24-bit per pixel image produced by an 8-megapixel digital camera (with 8 million of those individual sensors) requires a total of 192 million bits (24×8 million), or 24 MB. As with sound, there are various compression schemes by which digital images can be represented using far fewer bits than this without noticeably losing image quality. The best known is JPEG – the acronym stands for 'Joint Picture Expert Group', the organisation that defined the format. Most digital cameras store images as JPEGs; in the case of an 8-megapixel camera, each JPEG image requires about 5 MB rather than 24. This kind of compression is most important of all in digital video – especially in portable devices, where storage may be a premium. One second of uncompressed, full high-definition (HD) digital video, with sound, requires nearly 1.5 gigabits per second. That is 15 billion 1s and 0s every second.

The fact that digital devices represent **information using binary numbers** is very important. It allows **real flexibility** in the way those devices **store** and **process** information

The fact that digital devices represent information using binary numbers is very important. It allows real flexibility in the way those devices store and process information. The message is independent of the medium. So, binary-coded information can be represented by laser light in a CD burner or in an optical fibre or by radio waves in a wireless network. They can be represented by electric voltages and currents inside integrated circuits and along cables and wires. Or they can be represented by magnetic fields in hard disks. And in this digital age, we are constantly surrounded by information in all these forms. This also makes it possible for different digital electronic devices to communicate with each other. So, for example, an image produced by a digital camera, stored as numbers on a memory chip using magnetism, can be sent as numbers encoded in radio signals, to a network router, which might send electric pulses along a wire, ultimately reaching a processor in your computer. You can back up the image as billions of tiny depressions on a spiral track in the surface of a CD or DVD. And because information can be represented in any medium that can represent numbers, this 'digital paradigm' is also future-proof. Information is represented by magnetisation on today's hard disks; high-capacity storage in the future will probably be quite different. Similarly, computer processors are currently manufactured from silicon or other semiconductors, but that need not be true in the future. Again, the medium is not the message.

Storing Bits

We need somewhere to put all these bits and bytes; an essential function of any consumer electronic gadget is the ability to store digital information. There are two basic types of storage: working memory and long-term memory. The working memory is normally in the form of several integrated circuits carrying RAM (random access memory). It is important that the processor can access any particular piece of information in the RAM very quickly indeed. When a device is

working, large amounts of digital information are continuously exchanged between the RAM and the device's processor. RAM is described as volatile: this simply means that information stored in it is lost when the device is switched off.

The firmware – that basic program that controls how a device operates – is normally stored in a different kind of chip, called 'read-only memory' (ROM). This is an integrated circuit soldered to the device's main circuit board. The information in a ROM chip cannot be overwritten, except under special circumstances, such as when the firmware needs to be updated. It is copied to the working memory at start-up, but remains unchanged on the chip, ready for the next time the device starts up.

So ROM is long-term storage but it cannot be overwritten, and RAM can be overwritten but is not long-term storage. Many devices also have long-term storage in which the information can be overwritten. Even a dedicated device such as a television has some way of backing up information, such as channel favourites, brightness and contrast, and the picture's aspect ratio. And of course, a media player can store digital representations of hundreds of songs, and you can erase tracks and add new ones. And a mobile phone has somewhere to store a list of names and numbers, along with text messages received and the details of the service provider. In these kinds of devices, the storage medium of choice is often 'flash memory'.

Flash memory is a solid-state device – it has no moving parts – so it is ideal for devices that may be subject to vibration or repeated movement. The name comes from the fact that when erasing information, large portions of the available memory in a flash chip are wiped, or 'flashed' at once. It is very light, too, and it takes up little space and retrieves stored information very quickly. All of this makes it ideal for devices where light weight and robustness are important: in mp3 players that you might listen to while running or working out at the gym; in mobile phones, which may be dropped, thrown into bags and pockets, and which

must be very portable. However, flash memory tends to be prohibitively expensive to incorporate much more than a few gigabytes of storage into a single device. Some PCs – in particular laptop, notebook and subnotebook PCs – have flash-based storage. This reduces the drain on battery power, and makes for a more robust and lighter machine – but for now, it does add significantly to the cost of the computer. Those USB memory sticks you carry around contain flash memory chips, as do the memory cards you can buy for your digital camera.

Of course, most PCs – and many other devices – use hard disks for long-term storage. Even a cheap hard disk drive can hold vast amounts of digital data. Until flash memory chips become cheaper, all media players that have more than a few gigabytes of storage are nearly all hard disk-based. The smallest hard disk drives are small enough to fit inside a small media player, but can have hundreds of gigabytes of storage space. Inside ROM, RAM and flash memory chips, binary digits are stored as electric charges or electric fields. But inside a hard disk drive,

The highly polished surface of a hard disk platter, with the read-write head poised just above it.

binary digits are stored using magnetism. A hard disk drive contains set of stacked discs that rotate together at high speed – typically 7,200 revolutions per minute (that's 120 times every second). Perilously close to both sides of each rapidly spinning disc is a read/write head, with a tiny electromagnet at its end. The head's electromagnets rapidly magnetise tiny regions of the discs' surfaces in one direction or the opposite, to represent the binary digits 0 and 1. Each read/write head is attached to the end of a pivoting arm that can sweep across the disc, so that it can position the read/write head next to any part of the surface of the rotating disc. Clearly this is a high-precision process.

Sending **information** from **one digital device** to another is a **matter of transferring streams of binary numbers** between the two devices

Making the Connection

Your consumer electronics gadgets would not be much use if they could not communicate with other such devices. Communication is vital in more subtle ways than you might immediately imagine – it's not just about phone calls, text messages and emails. Yes, your mobile phone must be able to communicate with a base station. But transferring music and video from your PC to a media player is also an example of one device communicating with another. And a PC must be able to send information to printers, and to and from other computers via the Internet or local networks. Electronic musical instruments may need to communicate digital information about note pitch, duration and volume to multi-

track recording software. Even normally disconnected devices may need their firmware updating from time to time. Sending information from one digital device to another is a matter of transferring streams of binary numbers between the two devices. The rate at which data pass along a connection is called the bandwidth, and is measured in terms of how many bits or bytes can be transferred each second.

The most obvious method of connecting two devices is to use a cable, and there is a wide variety of different ones available. The most common is the USB cable. A host of different devices, including digital cameras, printers and scanners, media players, and mobile phones can connect to each other – or more normally to a PC – via a USB cable. The current standard, USB 2.0, allows data transfer at up to 480 megabits per second (60 MB per second). At this speed, that 4 MB mp3 music track described above would shoot along the cable in a fraction of a second. USB has the added benefit that it can charge the battery in a portable device while information is being transferred. Another common wired connection is the Ethernet cable – it looks like a slightly plump telephone cable, with plugs similar to those on a telephone cable at either end, too. Originally designed for connecting PCs together to form networks, Ethernet cables can also carry information to and from attached storage devices, video games consoles, printers, and network hubs and routers. The current fastest Ethernet technology, called gigabit Ethernet, transfers information at a rate of up to one gigabit per second – although a fibre-optic version of the Ethernet cable can achieve speeds ten times that.

It is far more convenient to send information through the air, so that you don't have to plug one end of a cable into each device. Like wired connections, wireless connections also take many forms. For example, information can be coded into invisible infrared radiation and passed from one mobile phone to another – this is actually not much more complicated than what happens when you point your remote control at the television. It's just infrared LEDs flashing on and off in patterns not unlike Morse code.

Bluetooth has been most commonly used in transferring image and music files between mobile phones and PCs, and of course providing wireless connections for mobile phone headsets.

More commonly, mobile phones use Bluetooth – a short-range system that codes information into high-frequency radio waves. Most people are familiar with this technology because their mobile phones are equipped with it. Wireless hi-fidelity headphones and remote controls for media players are also becoming popular – headphone wires can be really annoying. The most recent version of Bluetooth, adopted in August 2007, may widen the uptake of this technology, because it has made the process of connecting two devices simpler and more secure. However, Bluetooth bandwidth is currently limited to 2.1 megabits per second. The next Bluetooth standard should increase this to 480 megabits per second, bringing it in line with the speed of USB.

Bluetooth tends to be used for 'personal area networks' because of its limited range. The other familiar wireless connection, Wi-Fi, is normally used to connect

devices together to form a larger wireless network. A Wi-Fi connection is the wireless equivalent of an Ethernet cable. It is very common in home networks and, of course, in 'wireless hotspots'. Just as with Ethernet, you can connect directly to suitably equipped printers, and share Internet connections between computers. But you can also, simultaneously, connect to some mobile phones and media players. Many consumers' experiences of Wi-Fi are not entirely positive, however. It can be unreliable – subject to interference or simply annoyingly difficult to administer if the set-up does not go smoothly. Sound familiar? A similar technology, called WIMAX, is available in some areas. It has a much higher bandwidth, and a greater range, than Wi-Fi, and it is very reliable, making it suitable for making wireless voice calls without using mobile phone network. Several cities have WiMax Internet connections available for subscribers – but you need a WiMax-enabled device to use it.

Observing the Protocol

There are two main modes of communication between connected devices. These are 'circuit switching' and 'packet switching' – each has a different way of delivering the information. In a circuit-switched connection, a dedicated channel is set up between the connected devices. This approach originated in the first telephone exchanges, where operators physically connected two callers' lines, forming a dedicated circuit that was available for the duration of a telephone conversation. This guarantees swift and consistent transfer of digital information. Mobile phone networks employ circuit switching to carry voice calls. However, when a channel is dedicated to a particular pair of devices, no other devices can use the medium, and available bandwidth can be effectively wasted when, for example, the connection is not actively in use. This is not a problem if you are connecting your digital camera to your own computer via a cable, but in a computer network, it can be. For example, if someone were to send a large file across a network, other

users' computers would have to wait until the transmission was finished before they could use the network.

The packet-switched approach involves breaking up digital information into small nuggets called packets. A packet is typically a few hundred bytes in size. A digital image sent from one PC to another on a packet-switched network is broken up into dozens or hundreds of packets by the originating computer. While they make their way across the network, these packets will be interspersed among other network traffic. Every packet might take a different route from all the others. Once all of the packets have completed the journey, the destination PC reassembles them to form an identical copy of the original file. When the network is busy, the packets take slightly longer to reach their destination, but the advantage is that the connection is always available.

Each packet on a packet-switched network carries extra information that allows it to be routed correctly to its destination. Exactly what extra information is carried on a packet depends upon what particular 'protocol' is being used, but it always includes the network address of the originating device and an address of the destination device, as well as the time it was sent. Most packet-switched networks use the Internet protocol (IP) to manage the addresses of connected devices. Every device connected to an IP network has an IP address. The Internet is a vast, global IP network of IP networks – an 'internetwork'. And every device connected to the Internet has a unique IP address.

Although mobile phone networks use circuit switching for voice calls, they use packet switching when they transfer data – for example, when a user wants to send and retrieve emails and multimedia messages, browse the Web or access information services made available by their network provider. The main advantage to users is that they are charged according to how much information they transfer, not the duration of the connection. Ethernet and Wi-Fi connections also use packet switching, while Bluetooth can operate in both packet-switched and circuit-switched modes.

That concludes our whistle-stop tour of the principles behind today's digital technologies. If you have followed these explanations, then you are more than ready for our journey into the future – both near and far, since digital, computer-based technology will continue to be the norm for many years to come.

The Future in Your Hands

Being 'connected' is of particular importance for portable devices. In a world in which so many of us are constantly on the move, portable devices offer real convenience. We love our pocket-sized devices, but there are drawbacks. For example, the more features a device has, the greater is the drain on a small battery. And the smaller and more feature-packed the device, the bigger the problem. It is also difficult to enter text on tiny keyboards – especially if you are used to full-sized computer keyboards and you need to type large amounts of text quickly. And then there is screen size: we are used to large screens at home, both with desktop computers and televisions. Magnifying small portions of a web page or a document is never quite the same as seeing the whole thing at once, and watching videos or looking at photographs on a small screen can be equally disappointing. One other problem is that, with so many different functions, the most useful portable gadgets are often the most difficult to use effectively. Finding your way around complicated menus can be frustrating for a non-technically minded consumer, who wants gadgets that 'just work'. Who wants to read through instruction manuals or search the Web for help?

Finding your way around **complicated menus** can be frustrating for a non-technically minded **consumer**, **who wants gadgets** that 'just work'

One solution to the problem of tiny keyboards, and to the problem of shrinking battery sizes, is simply to use a slightly larger device. A class of computer called subnotebooks lies between the notebook PCs and smaller, handheld devices – in both size and power. Subnotebooks are almost small enough to fit in a pocket, and they are very light, but they maintain most of the functionality of genuine notebooks. Most of these small computers have the ability to connect to mobile phone networks as well as Wi-Fi networks, for browsing the Web as well as for making phone calls.

The mainstay of the portable gadget world is the mobile phone. In 2007, consumers worldwide bought more than a billion mobile phones. The total number of subscriptions to mobile services passed 3 billion for the first time in July of the same year; that's nearly one mobile for every two people on Earth. It took about twenty years for the first billion subscriptions, two and a half years for the second billion, and less than two years for the third. The number of people using mobile phones is actually just over 2 billion, because a significant number of people have more than one subscription.

Mobile phones are popular across all ages; a survey carried out at the end of 2006 found that around 90% of children aged 12 in Britain own a mobile phone. In 2007, according to the UK's Mobile Data Association, an average of 5 million texts were sent every hour in Britain – a total of around 50 billion for the year. Most phones sold in the past couple of years have built-in cameras; increasingly, these cameras have picture quality that rivals that of expensive stand-alone digital cameras. Worldwide in 2006, consumers bought 500 million camera phones, and a 2007 study by Strategy Analytics predicted that one-third of the global population will own a camera phone by 2011. These numbers are staggering. In countries with the highest mobile phone use, and with the most advanced mobile infrastructure, mobile television services are already thriving, and millions of people also use their phones as a form of payment, taking the place of credit cards.

Since 2004, mobile phone users in Japan have been able to use a facility called Osaifu-Keitai (literally 'mobile wallet'). This is a 'contactless' payment system that can act as cash, a credit card, and a direct ticket payment and booking system for transport and concert tickets. To use the system, customers simply place their phones near to a special reader, information passes between phone and reader via short-range radio signals, and the transaction is carried out in seconds. This system is being trialled in several other countries.

Smartphones

So-called 'smartphones' typically incorporate the ability to read and send email, browse the Web, download and run new software, and play games. These devices are basically handheld general-purpose computers without the processing power or storage capability of a desktop or portable personal computer.

Smartphones bring real convenience, especially when they include many different functions within a single device that fits in your pocket. Being able to make or take a mobile phone call without removing the earphones you have been using to listen to your favourite music tracks, while also looking at your diary or address book, is a real bonus. Add to that the ability to carry precious memories as photographs and videos, and to access and even contribute to a world of information via the Internet, and it is no wonder portable devices are so popular and desirable. There are other handheld, pocket-sized devices that are not mobile phones at all, but which offer all of the other functions present on a smartphone. In addition to carrying storage for music, digital photographs and video, and documents, these gadgets are typically able to connect to wireless networks, enabling users to check email, browse the Web, and download music or video.

Nokia's popular N95 smartphone, along with the equally popular Blackberry smartphone, by Research in Motion.

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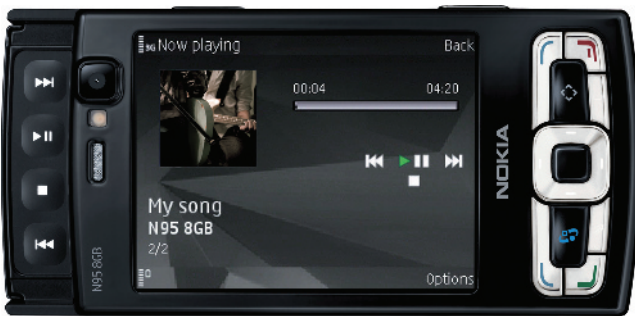
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Rapid uptake of **mobile phones in poorer nations** seems to be part of the reason why consumer **electronics** industry surveys often refer to such nations as **'emerging markets' rather than** 'developing countries'

Mobile phones are not only changing people's lives in the rich nations. They are one of the few consumer electronics devices to have a truly global impact. Rapid uptake of mobile phones in poorer nations seems to be part of the reason why consumer electronics industry surveys often refer to such nations as 'emerging markets' rather than 'developing countries'. You might see this as a positive development, since the term 'developing countries' can be seen as patronising. Alternatively, you might think it is a reflection of a cynical, profiteering industry that will go all out for profits wherever it can find them. After all, do people in poorer nations truly need to feel they should buy into our obsession with digital technology?

Well, there is an argument that electronics really can be beneficial to people. Mobile phones can be an effective tool in the fight against poverty. For example, they enable farmers in remote areas to check out current market prices for their produce. One scheme, run by the Senegalese company Manobi, already provides a service to tens of thousands of farmers, allowing them to trade directly via their phones. Camera-equipped mobile phones allow farmers to make and share tips or techniques via video clips, or warn of the spread of disease. Other workers use their mobile phones to find work in nearby towns and villages; people living far from doctors receive basic medical diagnosis and advice from doctors without having to travel tens of miles to the nearest surgery. Is this digital technology

making a real positive difference to people's lives, or is it a slippery slope towards a world in which everyone has to remember to charge their mobile phones and where people pay a significant amount of their income just to keep up with the technology? Mobile phones and airtime cost a higher proportion of a poor person's income than a rich person's.

Many people in poor and remote areas have begun using camera phones and smartphones in the same ways as people in richer nations use their PCs. Jan Chipchase, who carried out research into mobile use for Nokia in several countries, has said 'If you ask people what the three most important things they carry are – across cultures, and across genders and across contexts – most people will say keys, money and, if they own one, mobile phone.' The continent with the fastest growth in mobile phone use is Africa. In 2001, there were about 25 million mobile phone users across the continent; by 2007, there were around 200 million. Around 65% of Africans live in areas covered by mobile phone signals – mobile phone services require much less infrastructure than traditional landline connections.

Mobile phone booth in South Africa.

On Display

Portable or not, most of our devices need some way of displaying information. The most basic display technologies are simply indicator lights, such as those annoying ones that flash to indicate hard disk activity or the fact that information is passing to and from the Internet via your router. These are normally LEDs (light-emitting diodes), which are great because they use very little electrical power. Those simple numerical displays you still find on many DVD players use LEDs, too. A variation on the ordinary LED is the organic light-emitting diode (OLED), which is already being used in a wide range of devices, including illuminated keyboards and mobile phone keys.

OLEDs can be used to make screens that can display images and video as well as just letters and numbers on a keyboard. Some mobile phones and some personal media players have small OLED screens, and in December 2007, Sony released the first televisions to use OLED screens. The future appears bright for this nascent technology – we'll gaze forwards in Chapter 4. Most personal media players and mobile phones use a more familiar and much more established technology: the liquid crystal display (LCD). And at present, LCDs dominate the television market, too – along with plasma display panels (PDPs) – and they are likely to dominate for another five years at least.

There are no physical keys on this concept keyboard designed by Art. Lebedev, so the keys can be of any shape and size and colour – thanks to an OLED surface.

LCDs and PDPs have begun the long job of displacing cathode ray tube (CRT) displays – the heavy and bulky glass tube at the heart of traditional television sets and computer monitors. Worldwide in 2007, consumers spent around $95 billion (£50 billion) on PDP and LCD televisions in 2007. Part of the popularity of LCDs and PDPs is due to the introduction of high-definition television, which has a resolution of either 1,920 columns × 1,080 rows (more than 2 million pixels) or 1,280 × 720 (nearly 1 million). A standard-definition TV picture in the UK has a resolution of 702 by 576 (just over 400,000 pixels). High-definition pictures demand a bigger screen. Because LCDs and PDPs are much thinner than CRTs, they can be incorporated into much bigger televisions without significantly adding to the weight. But even thinner displays will be needed ultimately, so that televisions can be bigger still – since there are still higher-definition television pictures to come. Even existing standards allow for pictures composed of 3,840 × 2,160 pixels (more than 8 million pixels).

A phosphor coating inside each cell of a plasma display panel produces red, green or blue light.
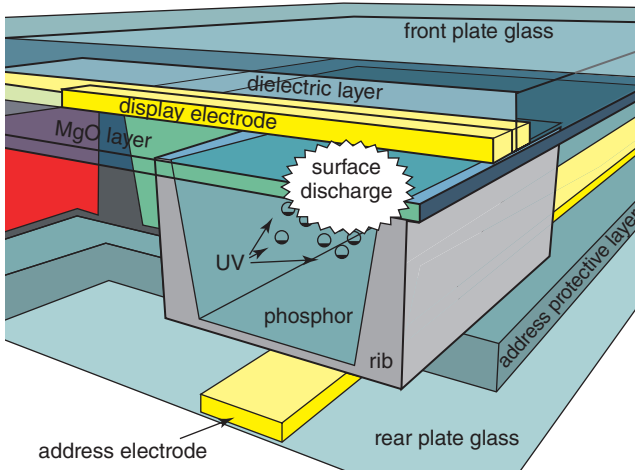
Digital Televisions

Each picture element (pixel) of a plasma display is composed of three subpixels – one that produces red light, one that produces green light and one that produces blue light. The human eye has only three types of colour-sensitive cell – one sensitive to red, one to green and one to blue. So by combining these three colours in the correct combination, three adjacent subpixels can produce the illusion of almost any colour. Each subpixel is a tiny, sealed cell.

The inside surface of each cells is coated with a phosphor – a substance that produces light when ultraviolet radiation strikes it. The ultraviolet radiation is produced when an electric field passes through an electrified gas, or plasma, which fills the cell. Each pixel is individually 'addressed' according to its distance 'along' and 'down' the panel. There are hundreds of thousands, or even millions, of cells – depending upon the screen's resolution – arranged as a grid that covers the whole screen. And plasma screens typically display a screen's worth of information 50 or 60 times every second.

Liquid crystal displays have been used in calculators, watches and many other devices with simple, small displays since the 1970s. An LCD consists of several layers – with glass at the front and a diffuse white light source at the back. The LCD makes use of a strange property of light called polarisation. There are two polarising filters, arranged at right angles to each other, so that they do not allow any light to pass through. Between them is a layer of liquid crystal: a liquid that consists of long molecules. An electric field passing through the liquid crystal causes the molecules to line up in an orderly fashion – like a crystal. As the molecules align, they affect the polarisation of light that passes through them. The result is that some of the light can now pass through the polarising filters. In a large LCD screen – as in a plasma screen – each pixel consists of a red, a green

An ultra-close-up shot of an LCD computer screen. From a normal distance, the background would appear white – because all the red, green and blue subpixels have the same intensity.
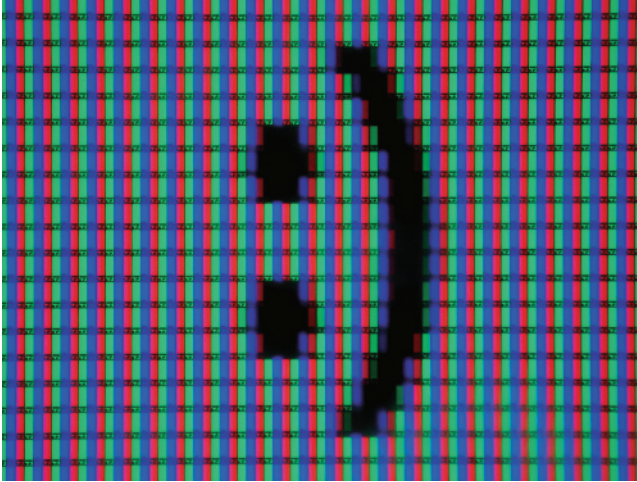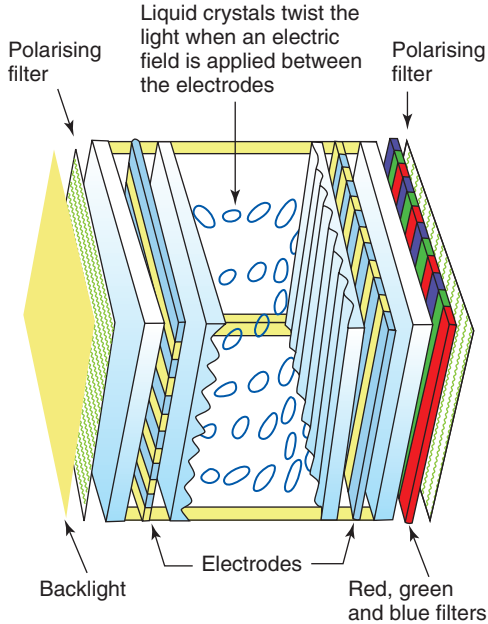

HTTP://WWW.FLICKR.COM/PHOTOS/AMAGILL/2433305075/SIZES/L/IN/SET-1819005/

and a blue subpixel. Just behind the front glass is a chequered colour filter with red, green and blue squares. Each subpixel sits directly behind either a red square, a green square or a blue one. The pixels are arranged in a grid, and each subpixel addressed individually. Miniature versions of LCD screens also feature in LCD projectors: the backlight is replaced by a projector bulb that is bright enough to project an image of whatever is on the LCD screen onto a screen or a wall.

In this chapter, I have painted a rounded portrait of today's consumer electronics – but with a very broad brush. I have investigated only a fraction of the devices that are available, and only scratched the surface of even what consumer

How an LCD display works.

Polarising
filter

Liquid crystals twist the
light when an electric
field is applied between
the electrodes

Polarising
filter

Backlight

Electrodes

Red, green
and blue filters

electronics can already do. Science fiction author Arthur C. Clarke famously wrote 'Any significantly advanced technology is indistinguishable from magic.' In a sense, our gadgets can do magic: they make moving pictures of real people appear on glass screens; they let us talk to people far away while we walk in the park; the virtual worlds we create are magical playgrounds in which anything is possible. The magic powers of consumer electronics are scalable. As we develop ever-faster processors, better storage devices with more capacity, faster connections by which we can transfer ever more digital information, and display technologies that are even better than the ones we already have, the magic will

grow and become more impressive. It all means that I will have to shell out even more of my hard-earned cash to satisfy my desires.

But how far will it all go? Where and when will it all end? And what kind of world will we be living in then? Will we all have cheap but immensely powerful and convenient house computers acting as intelligent personal computers? And if so, is that something you will want? Whatever happens, we consumers will play a vital role in marshalling the progress of these technologies – for the foreseeable future at least. But it is the consumer electronics industry that will be forging that progress. Designers, electronics engineers, physicists, materials scientists, software engineers, factory owners, factory workers, venture capitalists, sales and marketing executives, advertisers, retailers and service providers – all of these people and more are instrumental in the lucrative industry behind consumer electronics.

And so, in Chapter 2, I'll try to answer the following questions about the industry of our desires. How and where are our gadgets designed and manufactured? What are the environmental consequences of making and using these objects of desire? How can the men and women of this huge, disparate enterprise continue to make the gadgets we love ever more appealing? And in a business where competition is a vital part of sustaining progress, will it ever be possible for all our gadgets to be fully compatible with each other?